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Department of Hydro and Power Development

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SIDNEY GS EARTH RESISTIVITY MEASUREMENTS

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Earth resistivity tests were conducted at the Sidney GS/TS site using the Wenner method and the results indicated a multi-layer earth structure at the site. A two-layer interpretation of the test data provided an adequate model for use in design type calculations.

1.0 INTRODUCTION

Sidney GS is a very old station with masonry buildings. The station has no security fence and is accessible to the public. Sidney GS and TS are located close to each other, on the east and west sides of Highway #33 respectively. The 6.6-kV equipment is located at the TS and the output of the GS is fed to the step-up transformer via 6.6-kV underground cables between the GS and TS. The grounding systems at the GS and TS may be interconnected via the neutral conductors of the 6.6-kV cable and a fault at the TS may increase the GPR and touch and step potentials at the GS. However, no calculations of grounding system performance at the GS or TS have been done to confirm any problem area. As a preliminary step, earth resistivity measurements were conducted near the station for use by the design group in the preliminary calculations of the grounding system performance at the station. The project was requested and funded by Hydraulic Plant Equipment Department.

2.0 TEST PROCEDURE

The Wenner method/1/ was used to measure the soil resistivity at four selected locations near the station. A Megger DET-2 ground resistance tester was used to take the Wenner readings. For each probe spacing, a second reading was taken with the test current injection reversed and the average value was used for the analysis. Also the Megger was calibrated using a 100 Ω resistor and the required correction factor was applied to the test readings. The resistivity surveys were done near the TS entrance, along the 115-kV and 44-kV rights-of-way and along Highway #33 on the east side. Figure 1 shows the layout of the GS and TS with respect to the resistivity survey locations. Two surveys in different directions were done at the TS entrance with the results averaged. The survey locations and the maximum probe spacing for each survey were limited by the accessibility as the site is congested with HV lines, access roads, bushy areas, the highway and the river.

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Safety precautions were observed during the tests in order to avoid any hazardous voltages that may appear in case of a system fault. Dielectric rated rubber gloves and safety shoes were used by all test participants while handling test leads and making connections. Personnel stepped onto rubber blankets near the instrument while taking measurements. Each measurement was performed only after all personnel were clear of the test probes and leads.

The tests were conducted on April 8, 1988. Assistance was obtained from Belleville District P&C staff in conducting the tests.

3.0 TEST RESULTS

The site is characterized by a thin layer of surface soil with gravel underneath as noticed while pushing ground rods into the earth. The weather was sunny and the surface conditions were dry grass and wet soil due to rain the previous night. The area along the rights-of-way (locations 2 and 3 in Figure 1) was swampy with water pockets. From the Wenner readings, the apparent resistivities were calculated using equation 7.1 of the Grounding Guide/1/. Tables 1 to 4 list the apparent resistivities for each location along with modelled values.

4.0 INTERPRETATION OF TWO-LAYER SOIL MODELS

The increasing resistivities with probe spacings clearly indicate a multi-layer earth structure at the site. A two-layer model, an upper layer of resistivity ρ_1 , thickness d and a second layer ρ_2 of infinite length, is often considered adequate for grounding system studies. Therefore, a two-layer soil model for each test location was interpreted from the field data using the graphical method described in Appendix D of the Grounding Guide/1/. The station ground resistance depends on grounding conductor spacings which normally range from the mesh size to the largest diagonal dimension of the ground grid. Therefore, for use in station ground resistance calculations the models were fitted to the data points at the larger probe spacings which give average resistivities at larger depths. Table 5 compares the two-layer model parameters for each location and Tables 1 to 4 list the modelled apparent resistivities along with the measured values. Figures 2 to 5 show the plot of the field data and the corresponding fitted model resistivity curve for each location.

As an alternate way of interpretation, all the Wenner data points at the four survey locations were plotted on the same graph and a two-layer model for station ground resistance was approximately fitted eliminating any scattered points. The last row of Table 5 gives the resulting model parameters.

For step and touch potential calculations, a two-layer model based on the Wenner results with probe spacings 1 to 5 m yields a top layer resistivity of 80 $\Omega.m$ at a depth of 1 m and a bottom layer resistivity of 320 $\Omega.m$.

TABLE 1
SOIL RESISTIVITY NEAR TS ENTRANCE

Probe Spacing (m)	Apparent Resistivity ($\Omega.m$)	
	Measured	Modelled
1	95.8	235.0
2	155.6	235.0
5	224.8	225.0
10	285.0	285.0
20	380.8	380.0

TABLE 2

SOIL RESISTIVITY NEAR 115-kV RIGHT-OF-WAY

Probe Spacing (m)	Apparent Resistivity (Ω .m)	
	Measured	Modelled
1	127.1	78.0
2	197.0	130.0
5	254.2	260.0
10	409.7	400.0
20	560.5	540.0
50	609.5	660.0
100	520.9	700.0

TABLE 3

SOIL RESISTIVITY NEAR 44-kV RIGHT-OF-WAY

Probe Spacing (m)	Apparent Resistivity (Ω .m)	
	Measured	Modelled
1	94.4	86.0
2	123.8	110.0
5	214.9	215.0
10	339.9	345.0
20	527.8	520.0
50	662.9	700.0

TABLE 4

SOIL RESISTIVITY ALONG HWY #33

Probe Spacing (m)	Apparent Resistivity (Ω .m)	
	Measured	Modelled
1	29.9	36.0
2	51.0	50.0
5	111.5	110.0
10	182.2	185.0
20	319.2	315.0
50	471.9	490.0
100	659.1	600.0

TABLE 5

FITTED TWO-LAYER MODEL PARAMETERS FROM WENNER DATA

Location	ρ_1 ($\Omega.m$)	d (m)	ρ_2 ($\Omega.m$)
TS Entrance	215	8	540
115-kV Right-of-Way	55	1	715
44-kV Right-of-Way	80	2	800
HWY #33	33	2	660
Avg Fitting to all data	50	1	700

5.0 DISCUSSION OF RESULTS

- a) The two-layer interpretation of the test data at all the four survey locations clearly shows a higher resistivity second layer at the site with ρ_2 of approximately 540-800 $\Omega.m$ as shown in Table 5.

The increasing resistivity with depth is consistent with the geology noticed at the site (glacial till over bed rock).

- b) The value of ρ_1 near the TS entrance is high compared to that at the other locations, probably due to the backfill and grading at the entrance.
- c) Referring to Table 5, the two-layer model which best fits the average of all the test points agrees reasonably well with the model for each test location. Therefore, the average fitted model can be taken as representative for calculating the station ground resistance.

6.0 CONCLUSION

- a) Wenner resistivity measurements near Sidney GS and TS indicated a multi-layer earth structure. This is consistent with the geology at the site.
- b) A two-layer interpretation of the Wenner data from the test locations at the site yielded the following range of resistivity parameters for use in the station ground resistance calculations:

$$\begin{aligned}\rho_1 &= 30-80 \Omega.m \\ d &= 1-2 \text{ m} \\ \rho_2 &= 660-800 \Omega.m\end{aligned}$$

- c) The following two-layer model parameters from an average fitting of all the data points at the site are recommended for design purposes:

For the station ground resistance,

$$\rho_1 = 50 \Omega.m, d = 1 \text{ m}, \rho_2 = 700 \Omega.m.$$

For touch and step potentials,

$$\rho_1 = 80 \Omega.m, d = 1 \text{ m}, \rho_2 = 320 \Omega.m.$$

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REFERENCES

1. Ontario Hydro, Guide for Grounding, 1982 Revision.

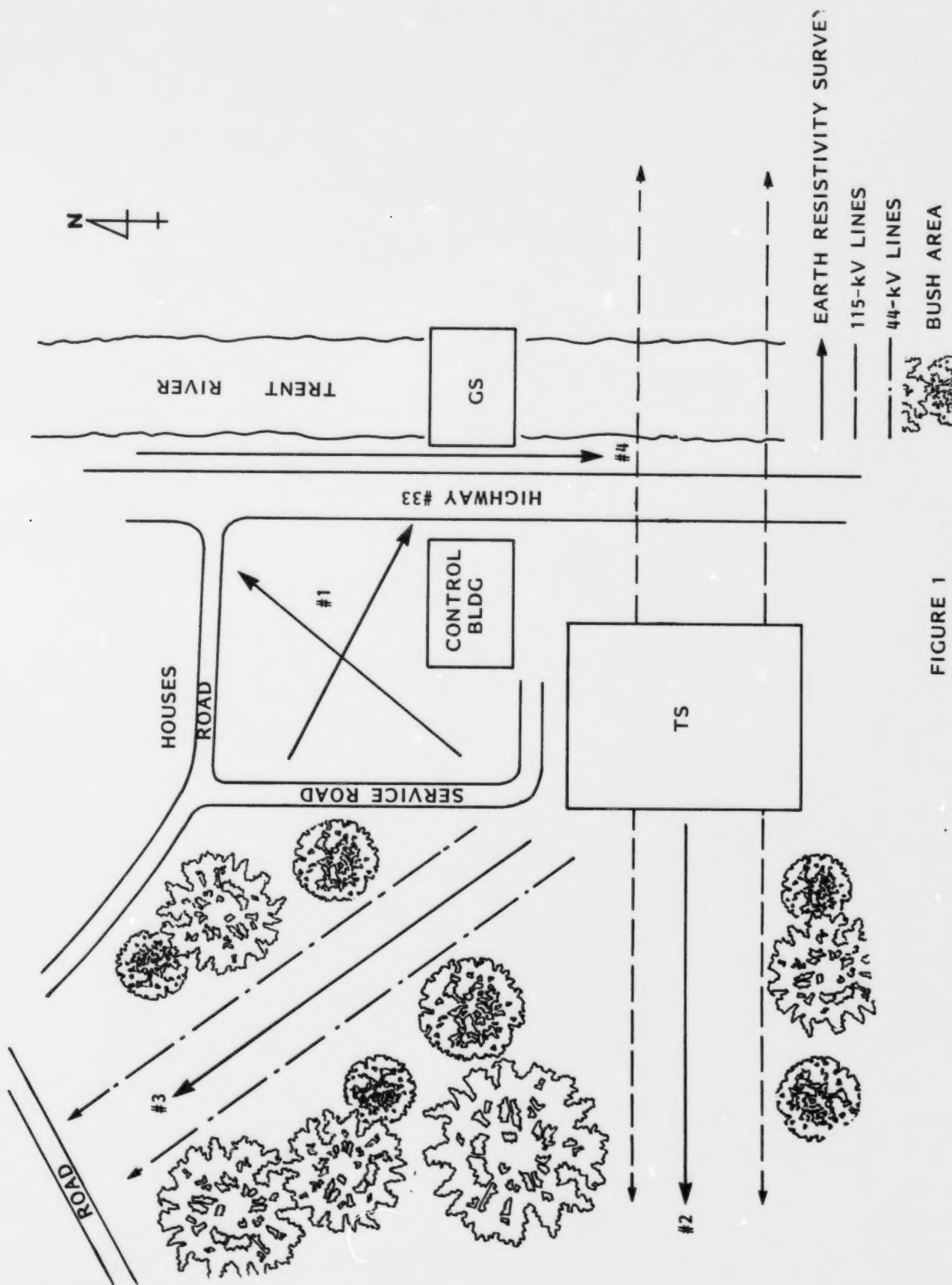


FIGURE 1
SIDNEY GS AND TS
LAYOUT WITH RESPECT TO EARTH RESISTIVITY SURVEYS

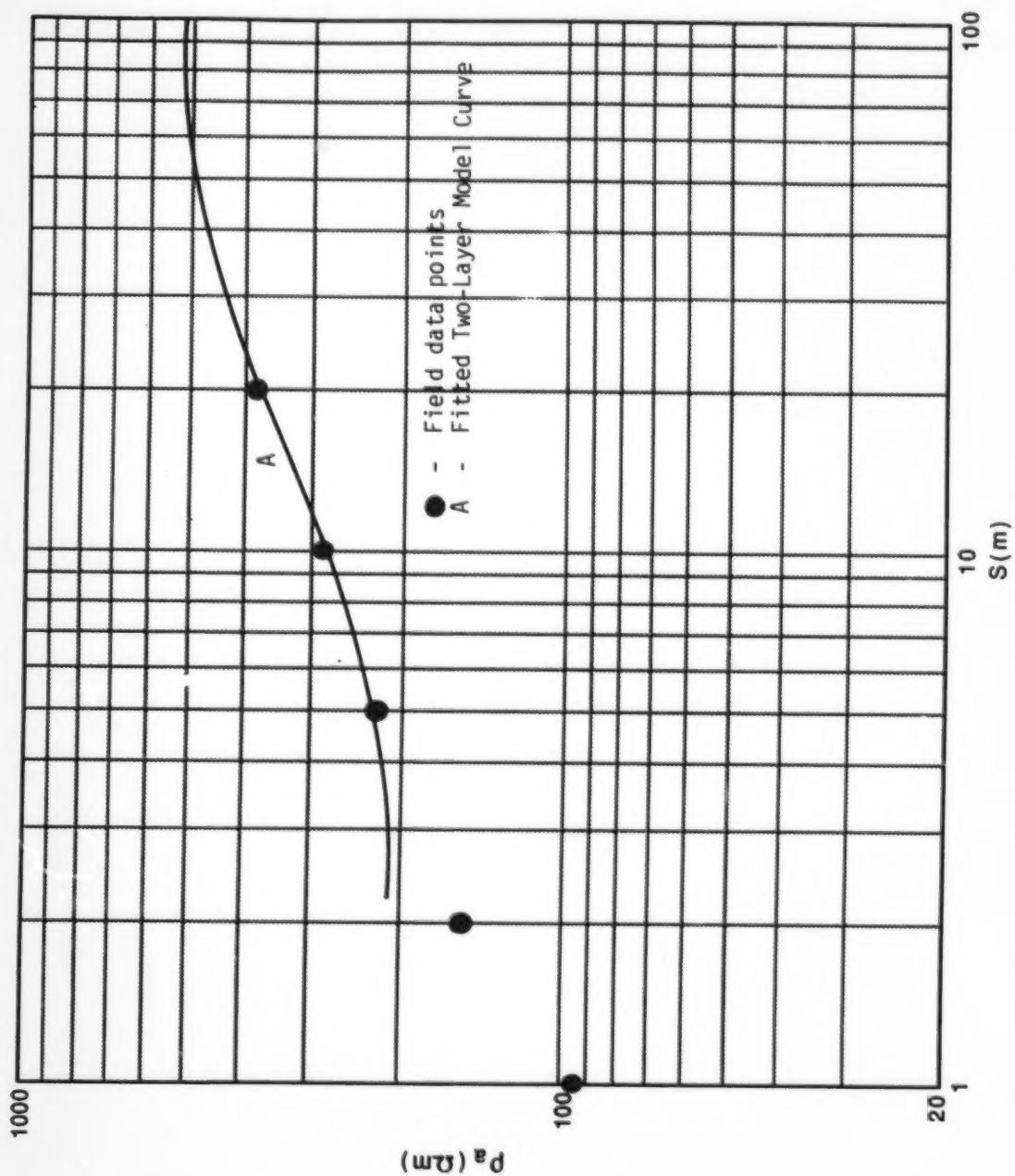


FIGURE 2
SIDNEY TS - APPARENT RESISTIVITY MODEL AT TS ENTRANCE

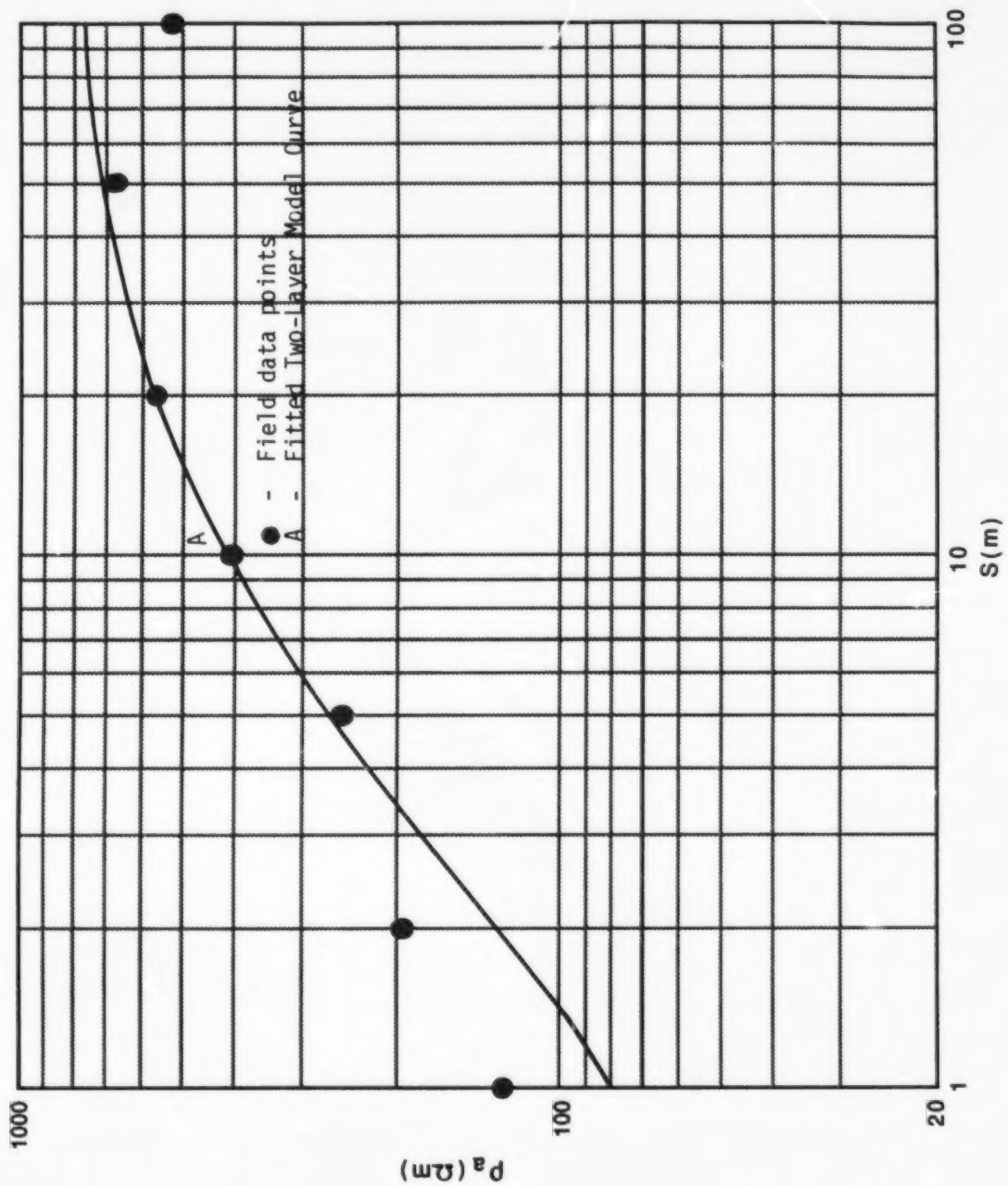


FIGURE 3
SIDNEY TS - APPARENT RESISTIVITY MODEL NEAR 115 KV RIGHT-OF-WAY

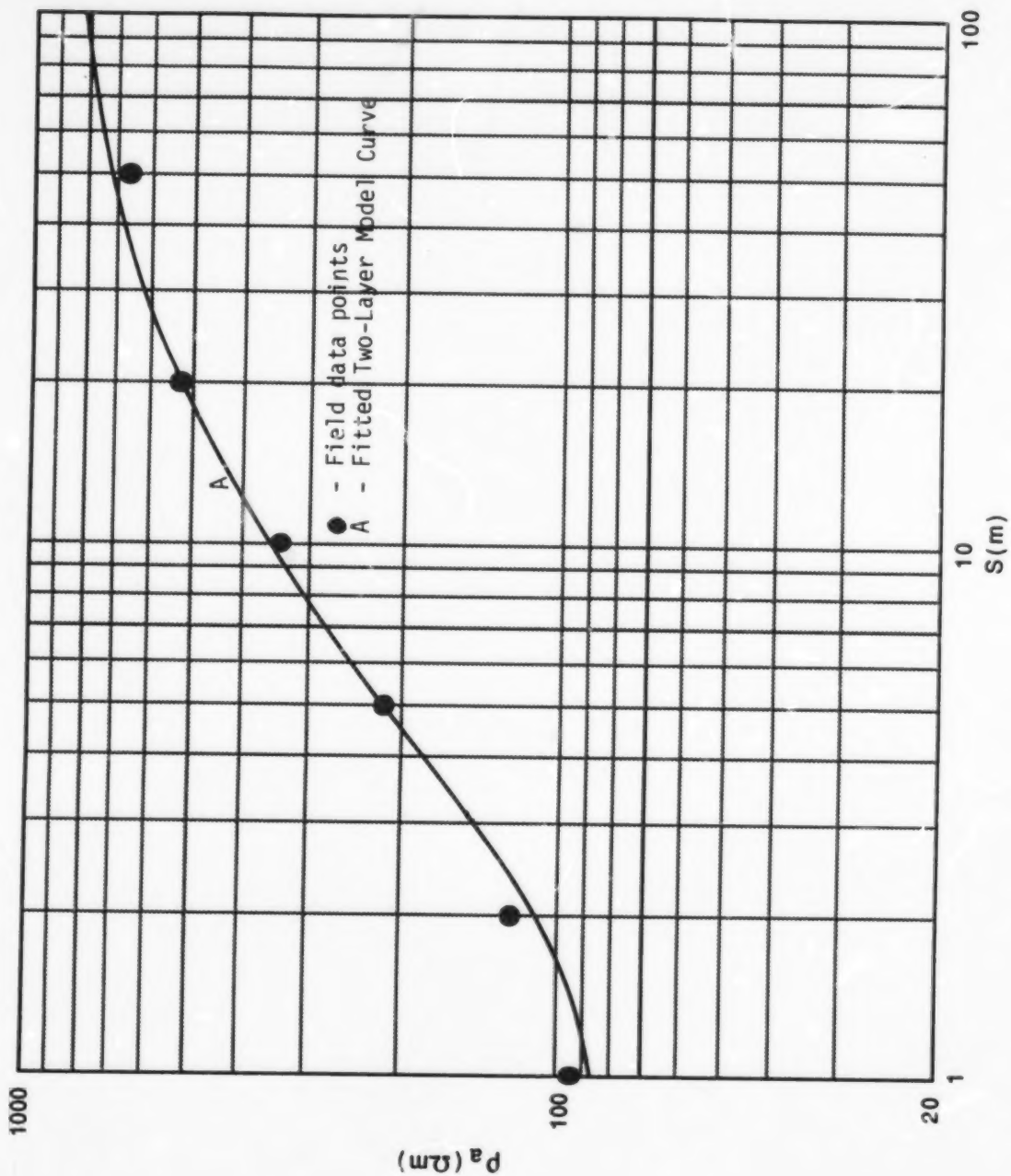


FIGURE 4
SIDNEY TS - APPARENT RESISTIVITY MODEL NEAR 44 KV RIGHT-OF-WAY

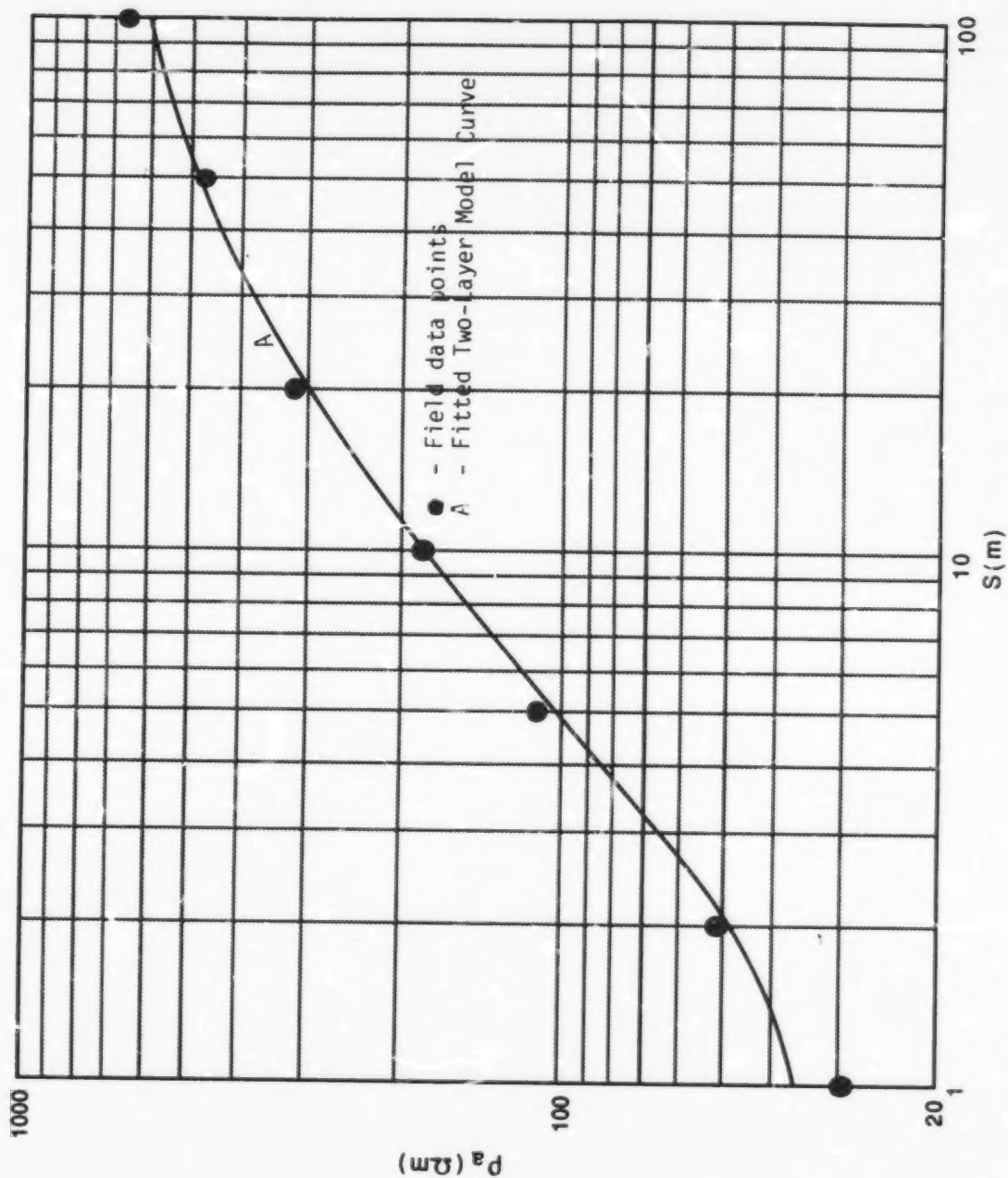


FIGURE 5
SIDNEY TS - APPARENT RESISTIVITY MODEL NEAR HWY #33